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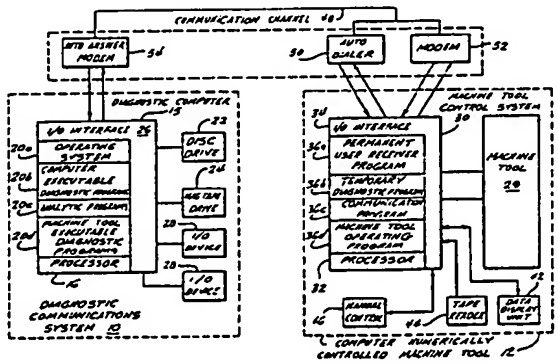
(54) **Unmanned diagnostic communications system for computer controlled machine tools.**

(57) An unmanned diagnostic communications system for analyzing the operation of a remotely situated computer controlled machine tool and for diagnosing any abnormalities disclosed during machine tool operation includes an auto dialer and MODEM coupled between the computer controlled machine tool and one end of a communications channel and an auto answer MODEM coupled between the other end of the communications channel and a diagnostic computer. In response to a test command entered by an operator to the remotely situated computer controlled machine tool, the auto dialer automatically establishes a communications link with the diagnostic computer through the auto answer MODEM. Thereafter, the diagnostic computer determines the identity of the remotely situated computer controlled machine and then transmits instructions to the computer controlled machine tool to direct its operation. In accordance with the program instructions from the diagnostic computer, the computer controlled machine tool transmits data indicative of machine tool operating characteristics to the diagnosing computer which is then analyzed by such data to detect and diagnose any machine tool abnormalities.



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This invention relates to computer controlled machine tools, and more specifically to an unmanned diagnostic control apparatus for automatically analyzing computer controlled machine tool operation and to diagnose any abnormalities disclosed during machine tool operation.

With the advent of computer controlled machine tools, machining operations which heretofore had been performed by a skilled machinist, can now be performed automatically by the machine tool in accordance with programmed instructions executed by the machine tool control system computer. In addition to reducing direct labor costs, use of computer controlled machine tools assures part uniformity because for so long as the computer controlling the machine tool executes the same program, each part produced by the machine will be identical to each preceding part produced thereby.

Due to their tremendous sophistication, such computer controlled machine tools are often quite complex. Although great care is taken during design to assure trouble-free computer controlled machine tool operation for long intervals, should a malfunction develop, machine tool complexity often forces skilled repair personnel to expend considerable effort and time to diagnose the cause of the machine tool malfunction. Since the per hour charge of such skilled repair personnel is often costly, and since machine down time often results in production delays which are very costly too, it is very important that the diagnosis and correction of machine tool malfunctions be made as

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EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
D,Y	US-A-3 882 305 (KEARNEY & TREAKER) * Whole document *	1-4	G 05 B 19/417
P,Y	US-A-4 296 756 (CYBER DIAGNOSTICS) * Page 9, lines 1-10; figures 1,6 *	1-4	
E	US-A-4 310 884 (CHEVRON RESEARCH) * Column 2, line 37 - column 3, line 26 *	4	
P,A	US-A-4 287 567 (UNIVERSAL INDUSTRIAL CONTROL DEVICES) * Column 4, line 60 - column 5, line 27 *	1-4	

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

G 05 B 19/417
G 05 B 19/405
G 05 B 19/408
G 06 F 15/42
G 06 F 15/50
G 06 F 15/74

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31-05-1983	RESSENAAR J.P.

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
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quickly as possible.

To facilitate rapid diagnosis of machine tool malfunctions, we developed the diagnostic communications system described in U.S. Patent 3,882,305. The diagnostic communications system described therein includes a pair of MODEMS, that is, modulator/demodulators, for coupling a remotely situated computer controlled machine tool across a communication channel to a diagnostic computer which stores diagnostic programs for analyzing the operation of the remotely situated computer controlled machine tool. In operation, linkage is established between the remotely situated computer controlled machine tool and the centrally located diagnostic computer by voice communication between the machine tool operator and the computer analyst at the diagnostic site. Thereafter, both the computer analyst and the machine tool operator condition their corresponding modems to enable digitally encoded information to be transmitted between the diagnostic computer and the remotely situated computer controlled machine tool. The digitally encoded information consists of instructions transmitted from the diagnostic computer to the computer controlled machine tool and machine tool characteristics, sensed during machine tool operation responsive to the previously received instructions from the central diagnostic computer, which are transmitted from the machine tool to the diagnostic computer.

One of the drawbacks associated with the diagnostic communication system described in our U.S. Patent 3,882,305 is that an analyst must be present at the diagnostic computer site to facilitate communication between the remotely situated computer controlled machine tool and the diagnostic computer. If it were possible to automatically establish communications between the diagnostic computer and the remotely situated computer controlled machine tool in response to a test command entered to the remotely situated computer controlled machine tool by an operator upon detection of any abnormality which is disclosed during machine tool operation, then the need for an

analyst at the diagnostic computer site could be obviated or, the analyst could be freed to perform other duties, thereby effecting a sizable savings in labor costs.

Accordingly, the object of the present invention is to provide an unmanned diagnostic communication computer system for automatically analyzing the operation of a computer controlled machine tool and for diagnosing machine tool abnormalities during machine tool operation.

The present invention provides an unmanned diagnostic communication system for automatically analyzing the operation of a remotely situated computer controlled machine tool and for diagnosing abnormalities disclosed during machine tool operation characterized by a diagnostic communication computer system programmed to monitor the operation of a remotely situated computer controlled machine tool in response to identifying data from the computer controlled machine tool indicative of the machine tool type and programmed to diagnose any machine tool abnormalities in accordance with data transmitted from the computer controlled machine tool indicative of machine tool operating characteristics; a communication channel between said diagnostic communication computer system and the remotely situated computer controlled machine tool for carrying instructions from the diagnostic communication computer system to the remotely situated computer controlled machine tool to direct machine tool operation and for carrying data from the remotely situated computer controlled machine tool indicative of the machine tool type and indicative of machine tool operating characteristics to said diagnostic communication computer system; and means coupled between said communication channel and said diagnostic communication system and coupled between said communication channel and the remotely situated computer controlled machine tool for automatically establishing a communications link between said diagnostic communications system and a remotely situated computer controlled machine tool in response to an operator-initiated command entered to the remotely situated computer controlled machine tool.

In accordance with the preferred embodiment, the means for automatically establishing the communication link between the diagnostic communication system and the remotely situated computer comprise an auto dialer and MODEM connected to the remotely situated computer controlled machine tool and, an automatic answering MODEM coupled to the diagnostic computer, to automatically initiate a communications link across a communications channel such as a telephone link, between the diagnostic computer and the remotely situated computer controlled machine tool in response to an operator initiated test command entered to the computer controlled machine tool. Following establishment of the communication link, the diagnostic computer interrogates the remotely situated computer controlled machine tool to ascertain its identity. Once the diagnostic computer is provided with information from the remotely situated computer controlled machine tool indicative of its identity, the diagnostic computer transmits control instructions to the computer controlled machine tool and, thereafter, receives information from the machine tool indicative of machine tool operating characteristics. By monitoring machine tool operation, the diagnostic computer can, in accordance with stored programs, diagnose any machine tool abnormalities disclosed during machine tool operations.

In the drawings, Figure 1 is a block diagram of the diagnostic communication system according to the present invention.

Fig. 1 illustrates the preferred embodiment of an unmanned diagnostic communications computer system 10 for monitoring the operation of a computer numerically controlled machining center such as CNC machining center 14, following an operator initiated test command entered to the CNC machining center. In the presently preferred embodiment, diagnostic computer system 10 includes a diagnostic computer 15, configured substantially identical to the diagnostic computer described in our U.S. Patent 3,882,305, and includes an electronic processor 16 which is coupled to four memory blocks 20a, 20b, 20c, and 20d, respectively,

containing an operating system, a set of computer executable diagnostic programs, a set of analytical programs and a set of machine tool executable diagnostic programs, respectively.

In addition to being coupled to memory blocks 20a through 20d, processor 16 is coupled to a disk drive 22 and to a magnetic tape drive 24 through an I/O interface 26. Disk drive 22 serves as the primary means for storing information concerning each of the CNC machining centers which may be interfaced to the diagnostic computer system for diagnostic analysis. The information on disk 22 concerning each CNC machining center includes data indicative of the machine type as well as machine design limit parameter data and data indicative of previously obtained machine operating characteristics which data, is referenced by the CNC machinery center serial number. Magnetic tape drive 24 serves as a back-up memory for disk drive 22 and may also be employed to initially input, and thereafter update, the programs stored in each of the memory blocks 20a, 20b, 20c, and 20d. Even though diagnostic computer system 10 is designed for unmanned operation, it may be advantageous to configure diagnostic computer system 10 with one or more input/output devices 28, such as a CRT display, a high speed printer or a keyboard printer, all coupled through I/O interface 26 to processor 16. I/O devices 28 enable an analyst, if present, to monitor diagnostic computer 15 and CNC machining center 14 operation.

Each of the computer numerically controlled machining centers interfaced with diagnostic computer system 10 takes the form of computer numerically controlled machining center 14 and includes a machine tool 28 which is coupled to and controlled by a machine tool control system 30. Although machine tool control system 30 may take the form of any well known machine tool control system, in the presently preferred embodiment, machine tool control system 30 is comprised of a KT/CNC control system manufactured by Kearney & Trecker Corporation and includes a processor 32 which is coupled through and I/O interface

34 to machine tool 28. Processor 32 is coupled to four memory blocks 36a through 36d which stores a permanent user receiver program, a temporary diagnostic program, a communication program and a machine tool operating program, respectively.

Input/output (I/O) interface 34 also couples processor 32 to each of data display unit 42, tape reader 44 and manual controls 46. Tape reader 44 serves as the means by which each of the four programs stored in memory blocks 36a through 36d, respectively, is initially entered, and thereafter updated. Output data generated during machine operation, is displayed on display unit 42, typically comprised of a cathode ray tube or plasma display, to the machine tool operator. In response to data displayed on display unit 42, operator-initiated commands can be entered to processor 32 through manual controls 46. It is through manual controls 46 that a test command is entered to processor 32 to initiate interface with diagnostic communications system 10.

To establish a communication link between CNC machine tool 14 and diagnostic communication system 10 across a communication channel 48, such as a long distance telephone line or a microwave channel connected at each end to a local telephone link, in response to an operated-initiated test command entered through manual controls 46, an auto dialer 50 and a communication modulator/demodulator (MODEM) 52 are each coupled between one end of communication channel 48 and I/O interface 26 of diagnostic computer 15. A MODEM 54 is coupled between the other end of communications channel 48 and I/O interface 26 of diagnostic communication system 10. In response to a command from processor 32, as transmitted to the auto dialer through I/O interface 34, auto dialer 50 automatically accesses auto answer MODEM 54 through communications channel 40 by transmitting a unique identifying code (the telephone number of auto answer MODEM 54) across communications channel 48. Auto answer MODEM 54 automatically responds to the identifying code transmitted by auto dialer 50 and,

following transmission of the identifying code, the auto answer MODEM automatically intefaces diagnostic computer 15 to communications channel 48 to permit transmission of data thereacross between diagnostic communication system 10 and CNC machine tool 14.

The diagnostic communications system of the present invention operates in the following manner. It is initially assumed that processor 32 of machine tool control system 14 is initially executing the machine tool operating program stored in memory block 36d to direct the operation of machine tool 28. If, during the execution of the machine tool operating program, a malfunction in either the machine tool or the machine tool control system occurs, then the machine tool operator enters a test command through manual controls 46 to processor 32. In response, processor 32 commences execution of the permanent user receiver program stored in memory block 36a. The permanent user receiver program stored in memory block 36a is substantially identical to the permanent user receiver program described in my U.S. Patent 3,882,305, and when executed by processor 32, it causes auto dialer 50 to access auto answer MODEM 54 through communication channel 48.

Once a communication link is established across communication channel 48 between processor 32 of CNC machine tool 14 and processor 16 of diagnostic computer 15, then processor 32 commences execution of the communications program stored in memory block 36c. The communication program stored in memory block 36c is substantially identical to the communications program described in my previously identified patent and controls the operation of MODEM 52 which, in combination with auto answer MODEM 54 and communication channel 48, carries the computer executable diagnostic programs and the machine tool executable diagnostic programs stored in memory blocks 20b and 20d, respectively, of diagnostic computer 15 to machine tool control system 30 which stores the program in memory block 32b. The computer executable diagnostic program and the machine tool executable diagnostic program are substantially

identical to the computer executable diagnostic program and the machine tool executable diagnostic program, respectively, described in my previously identified patent, and when executed by processor 32, they cause both machine tool 28 and processor 32, respectively, to generate data indicative of machine tool and machine tool control system operating characteristics, respectively, which data is then transmitted across communciation channel 48 to diagnostic computer 15. Processor 16 of diagnostic computer 15 analyzes the diagnostic data in accordance with the analytic programs stored in memory block 20c, which programs, are substantially identical to the analytic programs described in my previously identified patent. Following analysis of the machine tool and machine tool control system data, information, indicative of the machine tool malfunction, is thereafter transmitted across communication channel 48 to machine tool control system 30 for display on data display unit 42 to an operator. In accordance with the diagnostic information displayed on display unit 42, appropriate measures can then be undertaken to correct any machine tool or machine tool control system malfunction, thereby permitting rapid return to a re-execution of the machine tool operating program.

The foregoing describes an unmanned diagnostic communication system for analyzing machine tool operating data and to diagnose any machine tool malfunctions identified by such data. By employing means in the form of an auto dialer, an auto answer MODEM, a communications link between the machine tool, the diagnostic communication system can be established automatically therebetween, thereby obviating the need to manually establish such linkage.

Although the illustrative embodiment of the invention has been described in considerable detail for the purpose of fully disclosing a practical operative structure incorporating the invention, it is to be understood that the particular apparatus shown and described is intended to be illustrative only.

CLAIMS

1. An unmanned diagnostic communication system for automatically analyzing the operation of a remotely situated computer controlled machine tool and for diagnosing abnormalities disclosed during machine tool operation characterized by a diagnostic communication computer system programmed to monitor the operation of a remotely situated computer controlled machine tool in response to identifying data from the computer controlled machine tool indicative of the machine tool type and programmed to diagnose any machine tool abnormalities in accordance with data transmitted from the computer controlled machine tool indicative of machine tool operating characteristics; a communication channel between said diagnostic communication computer system and the remotely situated computer controlled machine tool for carrying instructions from the diagnostic communication computer system to the remotely situated computer controlled machine tool to direct machine tool operation and for carrying data from the remotely situated computer controlled machine tool indicative of the machine tool type and indicative of machine tool operating characteristics to said diagnostic communication computer system; and means coupled between said communication channel and said diagnostic communication system and coupled between said communication channel and the remotely situated computer controlled machine tool for automatically establishing a communications link between said diagnostic communications system and a remotely situated computer controlled machine tool in response to an operator-initiated command entered to the remotely situated computer controlled machine tool.

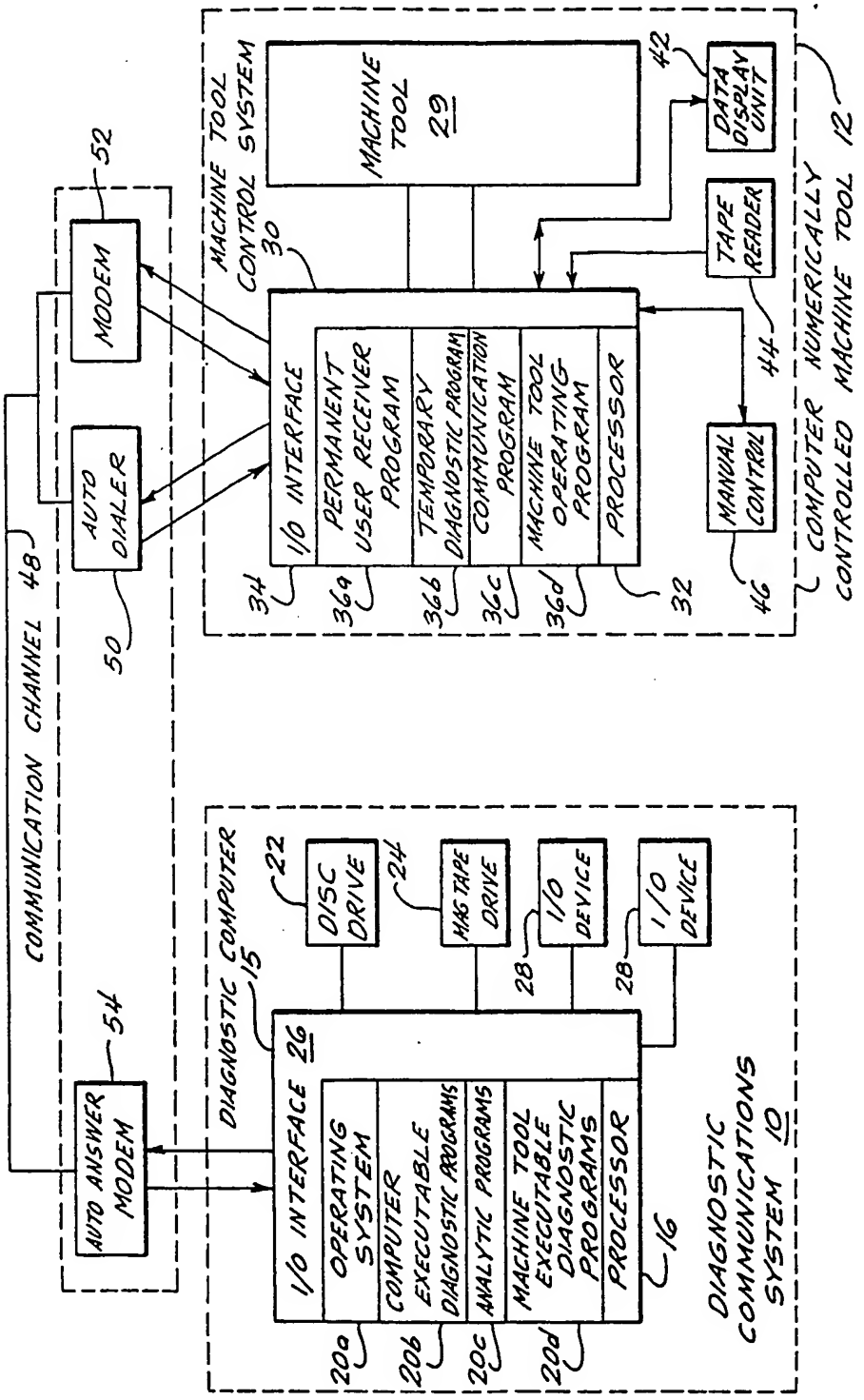
2. The system according to claim 1, characterized in that said diagnostic communications computer system comprises a processor; a first block of memory containing an operating system for directing the operation of said processor; a second block of memory containing computer executable diagnostic programs which, when executed by the machine tool control system of a computer controlled

machine tool, cause the transmission of data across said communication channel to said processor indicative of machine tool control system operating characteristics; a third block of memory containing machine tool executable diagnostic programs which, when executed by the machine tool control system of a computer controlled machine tool, cause the transmission of data across said communication channel to said processor indicative of machine tool operating characteristics; and a fourth block of memory containing analytic programs which, when executed by said processor, allows said processor to diagnose computer controlled machine tool abnormalities from said data transmitted across said communication channel indicative of the machine tool control system operating characteristics and machine tool operating characteristics; an input/output interface for coupling said processor to said means for automatically establishing a communication link between said diagnostic communication system and said remotely situated computer controlled machine tool; and a disk drive coupled through said input/output interface to said processor for storing information indicative of the type of computer numerically controlled machine tool interfacing said diagnostic communication system and of the type of computer executable diagnostic program and machine tool executable diagnostic program to be transmitted from said second and said third memory blocks, respectively, to said machine tool control system during diagnostic analysis thereof.

3. The system according to claim 1 or 2, characterized in that said communication channel comprises a long distance telephone line.

4. The system according to claim 1 or 2, characterized in that said communication channel comprises a microwave link coupled at each end to a local telephone line.

5. The system according to claim 1, 2 or 3, characterized in that said means for automatically establishing a communication link between said diagnostic communication system and the remotely situated computer controlled machine tool comprises an auto dialer coupled between the control system of a computer controlled machine tool and said communication channel for automatically transmitting an identifying code in response to a test command entered to the machine tool control system by an operator; a communications modulator/demodulator coupled in parallel with said auto dialer for transmitting data between said communication channel and the machine tool control system; and an auto answer communications modulator/demodulator coupled between said communications channel and being automatically operative in response to the identifying code transmitted by said auto dialer across said communication channel to transmit data between said communication channel and said diagnostic computer.


DIAGNOSTIC COMMUNICATIONS SYSTEM 10
DIAGNOSTIC COMPUTER 15
I/O INTERFACE 26
OPERATING SYSTEM
COMPUTER EXECUTABLE DIAGNOSTIC PROGRAMS
ANALYTIC PROGRAMS
MACHINE TOOL EXECUTABLE DIAGNOSTIC PROGRAMS
PROCESSOR 16
20a
20b
20c
20d
DISC DRIVE 22
MAG TAPE DRIVE 24
I/O DEVICE 28
I/O DEVICE 28
AUTO ANSWER MODEM 54
COMMUNICATION CHANNEL 48
MODEM 52
AUTO DIALER 50
COMPUTER NUMERICALLY CONTROLLED MACHINE TOOL 12
MACHINE TOOL CONTROL SYSTEM 30
I/O INTERFACE 34
PERMANENT USER RECEIVER PROGRAM 36a
TEMPORARY DIAGNOSTIC PROGRAM 36b
COMMUNICATION PROGRAM 36c
MACHINE TOOL OPERATING PROGRAM 36d
PROCESSOR 32
MACHINE TOOL 29
DATA DISPLAY UNIT 42
TAPE READER 44
MANUAL CONTROL 46

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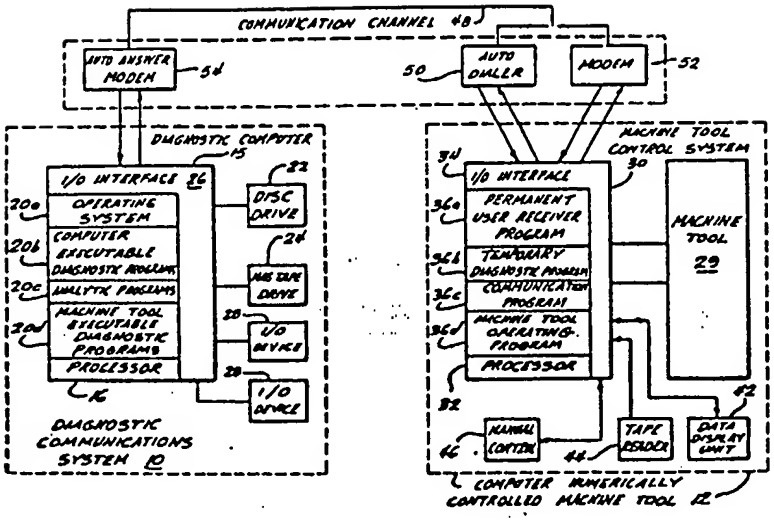
COMMUNICATION CHANNEL 48
AUTO ANSWER MODEM
54
50
AUTO DIALER
MODEM
52
DIAGNOSTIC COMPUTER
I/O INTERFACE
20a
OPERATING SYSTEM
20b
COMPUTER EXECUTABLE DIAGNOSTIC ROUTINES
20c
ANALYTIC PROGRAMS
20d
MACHINE TOOL EXECUTABLE DIAGNOSTIC PROGRAMS
PROCESSOR
16
22
DISC DRIVE
24
MAG TAPE DRIVE
28
I/O DEVICE
28
I/O DEVICE
DIAGNOSTIC COMMUNICATIONS SYSTEM 10
MACHINE TOOL CONTROL SYSTEM
30
34
I/O INTERFACE
36a
PERMANENT USER RECEIVER PROGRAM
36b
TEMPORARY DIAGNOSTIC PROGRAM
36c
COMMUNICATION PROGRAM
36d
MACHINE TOOL OPERATING PROGRAM
PROCESSOR
32
MACHINE TOOL
29
42
MANUAL CONTROL
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TAPE DEVICE
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DATA DISPLAY UNIT
COMPUTER NUMERICALLY CONTROLLED MACHINE TOOL 12